THE SURFACE HISTORY OF MONARO, N.S.W.

By Frank A. Craft, B.Sc., Linnean Macleay Fellow of the Society in Geography.

(Plate ix; four Text-figures.)

[Read 26th July, 1933.]

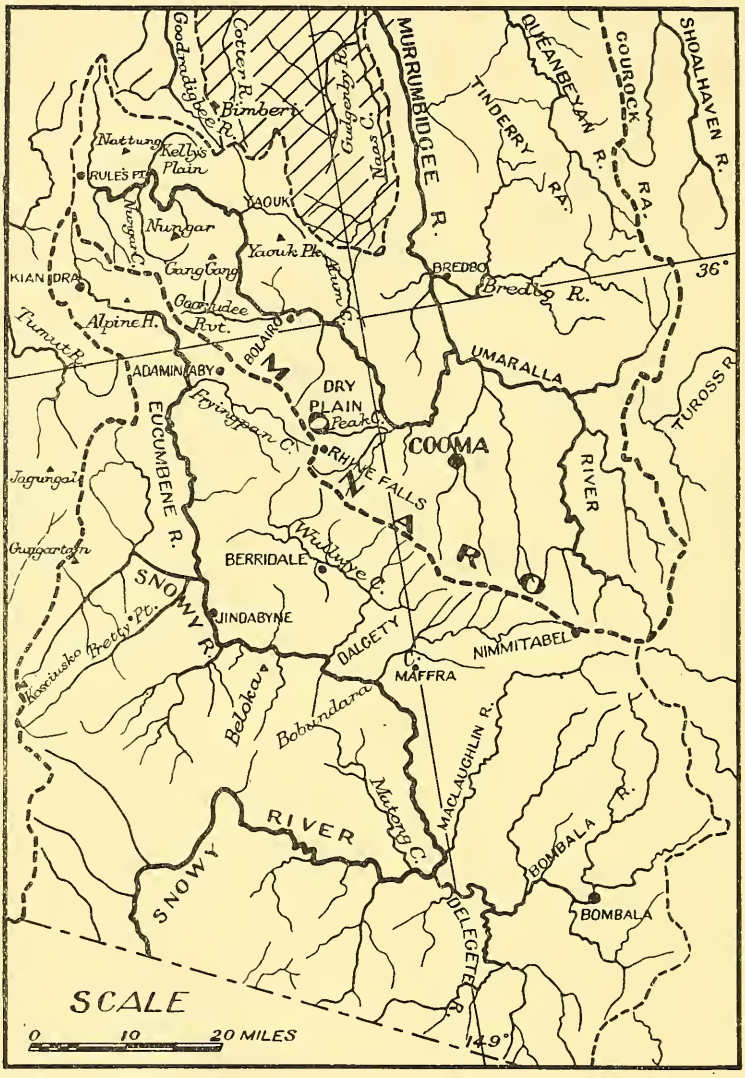
In this paper, the normal landscapes found in part of the south-eastern highlands of Australia are described, and regional surfaces of erosion are correlated with those already determined in the Shoalhaven Valley. The plateau has a terraced appearance which is held to be chiefly due to normal erosion in stages, as opposed to the idea of differential uplift of a common surface: the stream patterns have changed very little over long periods of time, and were evolved from longitudinal streams modified, perhaps, by ancient depressions in the primary surface. The northerly section of the Main Divide to the north of Monaro is not of much tectonic consequence, but the Victorian main divide has a general easterly extension towards the Pacific coast, and is convex to the ocean. In addition, the Tertiary drifts of Kiandra are held to be an expression of changing hydrography rather than of tectonic interference.

Introduction.

The name "Monaro" is sometimes applied to the whole extent of the higher plateau in south-eastern New South Wales, but it belongs specifically to the watershed of the Snowy and Murrumbidgee Rivers between Rule's Point and Nimmitabel. The more restricted sense of the word is used here, and most attention is paid to a strip of country extending some 20 miles on either side of the divide. The features of the Cooma district and the long northerly course of the Murrumbidgee are being treated separately by Dr. W. R. Browne, to whom due acknowledgment is made for references to his area, and for his exposition of its features and problems. Former accounts include the admirable narrative of Rev. W. B. Clarke (1860), the systematic work of Sussmilch (1909) and Griffith Taylor (1910), and references by David (1908), Andrews (1910) and Browne (1928), so the broad outlines of the surface features are already known, although they have been studied with an eye to tectonic history rather than surface classification, an aspect which repays detailed study.

Scenery and Topography.

The scenery and stream patterns fall into a few simple types with occasional overlapping when the major controls of climate, rock character and elevation combine in almost equal proportions: thus the appearance of alternate basins and narrows which is characteristic of the Eucumbene and upper Murrumbidgee Rivers extends into the high plateau about Kiandra, but the treeless Monaro plains and slopes, the ridge areas and the forested, dissected Umaralla plain give sharply defined scenic contrasts with abrupt passages from one to another. Five types may be recognized, as follows:



Text-fig. 1.—Locality Map. Part of the Victorian boundary is shown in the extreme south-west: a heavy broken line represents the Main Divide, lighter broken lines show other significant divides, and the Federal Capital Territory is shaded.

1. *The High Plateau.*—The sources of the Murrumbidgee and Eucumbene Rivers are comprised in this division: the elevation is consistently great, from 4,000 to 5,800 feet above sea-level, the hills are dome or hummock shaped, except where weathering basalt flows give rectangular outlines, and they are separated by wide valleys of gently concave section. The streams are widely spaced, with extensive marshes and swamps at all levels, up to 2 miles in width, and the Murrumbidgee above Rule's Point glides over black, peaty soil that has accumulated

as the result of a prolific growth of shrubs and swamp grasses. The main physical control appears to be climate: the rainfall is heavy (63 inches at Kiandra), frosts occur during 9 or 10 months of each year, and exert a powerful disruptive influence over the whole landscape. Rainstorms sweep away the weathered rock, and both minor surface features and streams tend to be eliminated.

2. *The Basin Country.*—Passing eastward of Kiandra, there is a general fall except in the peaks to the north of the Murrumbidgee, and with this fall comes the subordination of certain features of the high plateau and the disappearance of others, such as the swampy valley plains with their accumulations of peaty clay. Rounded forms are the expression of normally weathering granite and fissile slate rather than the dominating features, and the breaks of slope between upland and hillside, and between hillside and valley floor are sharp and distinct (see Plate ix). The courses of the main streams show alternate basins and narrows: the Murrumbidgee flows from its headwater plain across a hard strike-ridge to Kelly's Plain, whence it passes to Yaouk by a narrow gorge ("the Gulf"), thence through a rather dissected level to Bolairo plain, and the narrower valleys and gorges leading to Bredbo. With the Eucumbene below Kiandra, the wider sections of the gorge do not assume a plain form until Alpine Hill is passed, where there is a sudden expansion and flats which are partly built up of coarse river drift. A further narrow place is met before the undulating Adaminaby plain is reached, beyond which are the Jindabyne levels, a gorge as Beloka ridge is crossed (quartzites, etc.), and the great terraced valley at Dalgety.

It will be seen that the "basin and narrow" topography is normal in this section, and there are abrupt passages from level plains and mature forms to steep ridges and canyons, with some steepening of the stream gradients: there are considerable alluvial deposits of both coarse and fine material in the basins, with an apparent maximum thickness of 100 feet at Yaouk, and the streams swing about in the plains. A general balance seems to have been established between erosive forces and the resistance of various parts of the country, with rather steeper river gradients on the harder rocks, and uniform cutting in most places, the exceptions being the head plain of the Murrumbidgee and the gorges above Alpine Hill, with lesser and greater downcutting respectively.

3. *The Treeless (Monaro) Plain.*—A considerable part of Monaro and the valley of the Snowy has the appearance of a plain when viewed from a distance: there are extensive areas of level country about the Main Divide, but elsewhere the original surface has been lowered to give a series of inclined plains which have been trenched with narrow valleys. In places the development of horizontal levels is favoured by the presence of basalt flows which filled valleys to the level of the ridge crests, and even built up the divide south of Cooma, eventually giving a treeless plain, now apparently extended westward by the clearing of granite country of a similar elevation. The valleys of the granite section are wide, terraced, and gently undulating with convex slopes, but the basalts have a considerable number of lagoons on their higher parts, with accompanying indefinite drainage, and sharp breaks of slope where various flows have been exposed by weathering and erosion.

The general rise to Kosciusko and the high plateau on the west of the Eucumbene-Snowy line is marked by the presence of narrow, steep sided valleys, whose contrast with the gentler and lower Monaro levels may be partly due to rapid cutting of deep valleys along cardinal lines of weakness, the quick removal of weathered material, and the absence of an effective layer of decomposed

rock to hold water and promote weathering. On the east, conditions appear to have allowed slower stream cutting, with concomitant gentler slopes, more effective weathering, and eventual general reduction. Thus the cutting streams of the Berridale and Dalgety districts are exposing well rotted granites in their beds, in areas where the lowering near watercourses has not been disproportionate to that of the channels themselves, and they contrast with the more powerful streams of the gorge country, which run over fresh rock as a general rule. In the granite peaks of the Federal Territory and Yaouk, rapid valley cutting may have assisted in the preservation of the high points, but outward-sloping separation planes also help, and small differences in chemical composition may be found to have a considerable effect on the rate of weathering.

4. *The Forested (Umaralla) Plain.*—The forested slopes of the Umaralla drainage contrast with the treeless plain, although the two are of a similar elevation. With the former, the high-level plain has been dissected by streams that fall from the swamps and undulations of its surface into steep-sided valleys, in which they have gentle grades through most of their winding courses. When the valleys approach the Murrumbidgee they are broad and flat-bottomed, with falling dividing ridges on either side of each, and a generally asymmetric cross-section: proceeding upstream, the ridge outlines become more angular as the valley sides close in, and dissection is not apparent on the Tuross divide, although the eastern extension of the plain into the coastal territory is trenched with deep gorges. There is higher land both towards Gourock and Nimmitabel, led up to by forested ridges.

5. *The Ridge Country (northerly Murrumbidgee).*—The features of this unique area are being described by Browne, who emphasizes the dependence of its topography on the existence of parallel zones of rock with great differences of resistance to weathering and erosion. Standing rather away from the river is the ridge country of Yaouk Hill and the basins of Bredbo and Queanbeyan Rivers, where the higher points fall gradually in a series of branching ridges, and where the slopes of dissected terraces take on a like appearance owing to the establishment of closely-spaced tributary streams which have not been subjected to a process of integration.

Physiography.

While the appearance of the country varies regularly from place to place, there is also a definite order in the succession of erosional features and levels that have been moulded to give existing forms. Sussmilch (1909) recognized a surface of reference which he termed the "Monaro peneplain", that was differentiated by warping and faulting to give horizontal or tilted blocks at various altitudes. Thus the Monaro peneplain at 3,300 feet in the Cooma district was conceived to have been co-extensive with the Yass-Canberra plain to the north, now at 2,000 feet, with a tilted surface developed between them along the Murrumbidgee. However, the hill crests and the benches rising to 3,000 feet or rather more along the course of the river could also be interpreted as lying in an extension of the high-level peneplain about Cooma, with the Yass-Canberra plain appearing as a much newer feature. Browne's work shows the probability of this explanation being correct, and a comparison might also be made with the neighbouring Shoalhaven Valley; the Monaro peneplain extends across the Umaralla basin and has a considerable development in the Shoalhaven area (Craft, 1932*a*), with a further extension into the Molonglo drainage to the north-west, and into the Canberra district, a lower peneplain at 2,000 feet (the "Shoalhaven Plain")

being directly comparable with the Yass-Canberra plain. The extent of erosion in Monaro since the development of the main levels is shown by Tertiary basalt flows, which may be considered briefly under two heads: those of Monaro and Kiandra.

The Monaro Basalts.

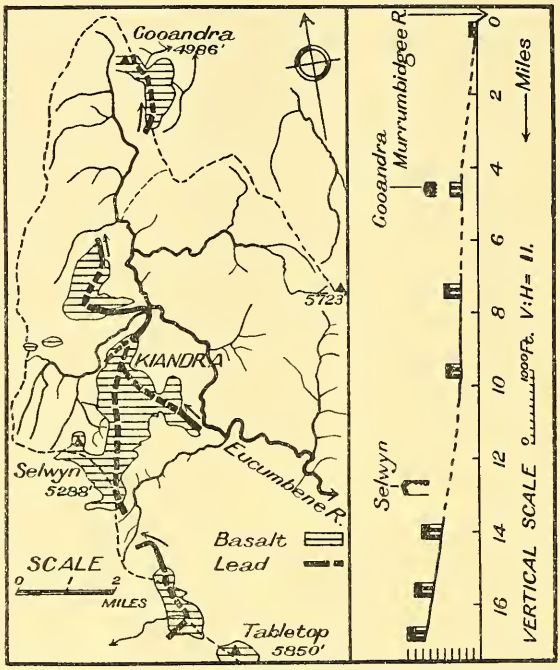
The undulating surface of Monaro peneplain falls from 3,200 feet near the Cooma-Berridale road to 3,000 feet towards Cooma, and to a slightly lower elevation near the Snowy at Dalgety. Narrow valleys were eroded in it to a depth of 500 feet as an extension of the lower peneplain (= Yass-Canberra or Shoalhaven plain), and were filled with basalt that buried stream gravels at various altitudes, the highest being at 3,750 feet on Dry Plain; basalt in that vicinity rises just over 4,000 feet, and to a similar elevation on the main divide near Nimmitabel. Much of the volcanic covering has been removed, so that considerable parts of the pre-basaltic surfaces are exposed in the Cooma district, and notable terraces have been formed in the high survivals between Cooma and Bombala. Where stream erosion has been most active in attacking the built-up surface, the buried valleys have been partly exposed with remnants of basalt adhering to their sides. Browne has noticed this feature to the north-west of Cooma, and it is also seen in the valley of Bobundara Creek near Maffra, while the valley of Goorudee Rivulet near Bolairo shows contact quartzite from the basalt contacts *in situ* between 3,250 and 3,500 feet; this latter overlies pebbles and white clay, and coincides with the modern valley slopes down to stream level (Plate ix).

Three stages are thus revealed: the general weathering and stripping of basalt sheets from the Monaro peneplain, the cutting of valleys through the basalt and their extension by headward erosion, and a process by which the basalt was removed from the filled valleys until, with the re-establishment of the former slopes, erosion has virtually ceased. The only outstanding example of the last-named is in a basin where old-age features were not being subjected to considerable erosive attack, and doubtless chemical weathering of the basalts was the main factor involved in their final destruction.

Kiandra Basalt and Lead (Text-fig. 2).—The greater part of the highland basalt of Kiandra covers a deep lead of stream drift and peaty clay ("lignite" of miners), with an extreme vertical range of 1,600 feet from the basalt at Rule's Point (4,250 feet) to Tabletop. Andrews (1901) showed that the main lead is 150 to 170 feet thick, and that it occurs in a rock-bound channel apparently falling northward across the present Eucumbene divide to the Murrumbidgee: on the southern bank of that river the drift is 50 feet thick, but this decreases to a few inches on the opposite side. The leads were covered with flows of basalt up to 300 feet in thickness, which form a capping for the monadnocks of Tabletop (5,850 feet) and Selwyn (5,288 feet), with a general northward fall of both upper surface and base, and an upward limit of 5,300 feet over the leads themselves. The present valley of the Eucumbene at Kiandra, with a depth of 600 feet, is clearly a post-basaltic feature, and gives a measure of active erosion in this section of high rainfall that contrasts with the static conditions noticed at Bolairo.

Andrews' sections show that the lead is not dissimilar to other upper Tertiary leads in this State, as the drift lies below the general level of the neighbouring plateau on either side, and the basalt has come up to this surface, although the specially active erosion of the district has removed parts of the

original containing walls on either side. Sussmilch and Jensen (1909) and Andrews (1910) classified the flows with the former's "monadnock basalts", but in view of the position of the greater part below the general level of the plateau, this can hardly be sustained without definite fossil evidence. The distinctive



Text-fig. 2.—Stream change in Kiandra district (after E. C. Andrews), also profile of lead channel, with basalt in plain black, and drift barred (drawn from details from E. C. Andrews).

feature of the lead is the presence of peaty clay, but this only differs from the light clays of such leads as the Shoalhaven by as much as the peaty deposits of the modern upper Murrumbidgee differ from the light-coloured flood-terraces of the Shoalhaven.

The origin of the leads is indicated by Andrews' levels, which show the profile of their channel base to be a normal curve of erosion, with no apparent discontinuities (the section of low grade at Kiandra is duplicated in part of the Eucumbene channel), and the lead deposits have a notably uniform thickness on both steeper and gentler grades. Allowing for normal variation, they show considerable uniformity in the basal "gutter wash", the lower horizon of peaty clay, and the sandy beds which predominate towards the upper levels. There appears to have been simultaneous deposition along the whole channel length, which may have been due to changes in the load and volume of the transporting stream, or to some violent interruption in its history: it has been suggested that such deposits were due to widespread subsidence bringing the country below sea-level (Wilkinson, 1882; Andrews, 1910), or to a blockage by basalt flows in one case (Craft, 1931), while warping and faulting, decreased rainfall or increasing maturity have also been mentioned as possibilities (Andrews, 1915), but none of these applies to Kiandra. The normal profile of the channel base has been noticed: it has not suffered notable warping or tilting, as the general level of the plateau at 5,000 feet or a little more extends northward from the head

of the lead to the headwaters of the Murrumbidgee, and there is no evidence of warping or faulting across the channel, or of blockage by basalt flows, which came later to cover the drifts. Likewise, there is no suggestion that the northerly country rose across the stream course to give conditions of still-water deposition at any stage, because the channel at Rule's Point is based on a peneplain level which included the plain divide at the head of the Murrumbidgee, only 130 feet above the lowest point of the drifted channel. The basalt extends on to this plain at Rule's Point, virtually clear of the drifted area: deposition as the result of subsidence cannot be admitted with deposits restricted to a definite channel, even though preservation on plains was made possible by basalt flows, and where they are of a reasonably uniform thickness at all grades, showing no great angular unconformity with their channel.

There is no alternative but to conclude that the drifts were laid down as the result of changes in the transporting stream itself which substituted deposition for erosion. Moreover, since the change was uniform along the whole channel, variation as the result of such external action as stream capture is unlikely, and the then-existing stream simply became incapable of gaining large fragments from the landscape, and of transporting all the material brought to the main channel: this may indicate an increased cover of vegetation and a decrease in the effective power of the flood stream. Modern conditions in the upper Murrumbidgee show that peaty deposits accumulate at grades as steep as 1 : 50, and with streams of less volume carrying more drift from weathering hillsides, it is probable that the thickness of peaty material would continue to increase until changing conditions altered the character of succeeding deposits, or renewed channel cutting. Another resemblance between modern conditions and those of the past is also found at the head of the Murrumbidgee, where the peaty layers are stratified, and contain bands of leached clay in places.

Summarizing, it is found that the drift of Kiandra lead was accumulated as the result of changes in vegetation and hydrography, without tectonic disturbance or the blocking of the stream channel. Some of the material was deposited at a grade of 1 : 65, which compares with grades of approximately 1 : 50 in steeper parts of the modern peaty clays, 1 : 58·5 of the Vegetable Creek lead (David, 1887), and 1 : 60 which may be observed in many existing stream terraces: the figures give some idea of the limiting slopes in such cases. Many of the leads of eastern New South Wales probably have a similar origin to that of Kiandra, although it may still be necessary to explain some by tectonic or basaltic interference. Furthermore, it will be seen that the basalts of Monaro and Kiandra give no evidence of differential uplift since they were poured out; on the contrary, they are associated with surfaces which bore the same relation to one another as they do now—a condition which gives a great measure of freedom in the interpretation of old erosional levels, for which Monaro peneplain may be used as a standard.

Monaro Peneplain.—A consideration of the upper Murrumbidgee shows that post-basaltic erosion has tended to reproduce pre-basaltic features in detail, with some downcutting in the Cooma district and in the various gorge and basin sections between Rule's Point and Bolairo; in general, the lowering due to this action is between 100 and 200 feet, and the lack of great local stream revivals shows that post-basaltic warping or faulting has been a minor factor in the development of surface features, a conclusion that applies equally to the Eucumbene-Snowy line between Kiandra and Maffra, with downcutting in excess

of 200 feet in the gorges above Alpine Hill, and greater valley formation at Kiandra. The main levels and terraces are thus older than the basalts, but their relationship to one another is not immediately evident, since correlation on the basis of height only is risky, and the meeting of surfaces is not infrequently obscured by other erosional features. The eastern portion is the simplest in this regard.

Eastern Monaro.—The Shoalhaven Valley shows that a pre-Tertiary peneplain exists at 3,000 to 3,400 feet above sea-level, and continues into the Umaralla basin: there is a normal rise to 4,000 feet between the two systems, and the peneplain may have been carved out of a master level about this relative position. This gives the status of the great peneplain of eastern Monaro, with high points rising to 4,300 feet in the level-bedded Devonian rocks to the east, and an extension from the Tuross divide to Berridale at 3,000 to 3,400 feet. To the south-west of Cooma and in the adjoining parts of the Snowy basin, this peneplain gives a perfectly even skyline that hardly shows the gentle undulations of its high points: along the northerly Murrumbidgee it is represented by extensive benches and hills with crests lying in a uniform summit plane between higher ridge masses, and by passes in the latter features, but towards Canberra its nature is essentially residual on account of its nearness to the effective edge of the highlands. In the opposite direction, to the south of Monaro ridge, the high points rise to a normal height of 3,200 to 3,500 feet, with the highest members on hard ridges or somewhat removed from converging streams, and with isolated residual points rising to a maximum of 4,700 feet on the Victorian border. There is a general lowering to 2,900 feet where the Maclaughlin River approaches the Snowy, and the main streams flow in broad terraced valleys some 400 to 500 feet lower, although they are only just cutting below the pre-basaltic levels. It is clear that there has been no effective Tertiary peneplanation here.

Thus the normal features of eastern Monaro may be described as a peneplain above 3,000 feet, with residual points rising 1,000 feet higher in the east, and the larger masses of Gourock and Tinderry attaining maximum elevations of 4,800 and 5,300 feet respectively, with uniform ridge lines about 4,600 feet, and a considerable further development to the west of the Murrumbidgee. It has already been concluded that Gourock Range was thrust above the Shoalhaven Valley before the formation of the Monaro peneplain (Craft, 1932*a*), and from what has been written above respecting surfaces in extra-Shoalhaven areas, it might be inferred that the high block now above 5,000 feet extended over eastern Monaro, where it has been planed down by erosion, leaving the modern high points on the Tuross divide in a superior position, although they were on the downthrow side of the fault. Western Monaro proves instructive in this respect.

Western Monaro.—The high plateau between the Kosciusko block and the head of the Murrumbidgee extends over a meridional distance of 50 miles at an altitude of 5,000 feet or a little more, and has a general width of 8 to 10 miles except in the vicinity of Jagungal (monadnock), where it is considerably wider, although furrowed by deep gorges. The greater part of this surface presents an even skyline with residuals rising to 500 or 600 feet above it, and to 1,500 feet in the single case of Jagungal, but the extension into the Murrumbidgee drainage has been maturely dissected, although the hills and ridges rise to a uniform summit plane. So far as the more northerly part is concerned, the terraces cut by the Eucumbene west of Alpine Hill and occurring between 4,400 and 4,600 feet are quite extensive, and penetrate to a depth of a mile or two from the

river in areas of softer rocks, although they are less perfect where the stream cuts across hard meridional bars, and they have been much dissected by gorge cutting. On the other hand, a very perfect set of plain levels is developed between 4,200 and 4,400 feet at the heads of the Murrumbidgee and Goodradigbee, forming a plain which comprises stream valley and divide indifferently, and encircles such high plateau ridges as Nattung (5,300 feet), where there are occasional passes about 4,500 feet. The plain is subordinated in the high ridges crossed by the Murrumbidgee below Rule's Point, but it is represented by swampy expanses on the courses of Nungar and Tantangara Creeks, separating Nungar (5,608) and Gang Gang (5,321) hills from the high country about Kiandra. The two surfaces are well defined with respect to one another: the lower plain at 4,200 to 4,400 feet has resulted from the dissection of the higher level above 5,000 feet, whose residuals become more scattered in the direction of Adaminaby, but whose ridges are prominent in the southern half of the Federal Territory.

Perhaps the most perfect development of the lower of these surfaces is found to the east of Kelly's Plain, where the Murrumbidgee crosses it in a gorge (Plate ix), and although the apparent eastward limit of the section is at Yaouk, foothills of the higher residual points about Yaouk Plain rise to 4,300 feet, and the gap at the head of the Cotter River is a little higher. The relationship of the plain above 4,200 feet to such high points as Yaouk, Morgan and Bimberi is clearly defined: it has been cut into their original mass, making them comparable with the high plateau immediately to the west, the superior elevation of a few points being doubtless due to their inherent resistance to erosion.

Passing eastward along Monaro ridge, the higher points are no longer found beyond Adaminaby, but the master surface is an extension of the lower level we have just been studying, and the general elevation of the divide is over 4,000 feet to Rhine Falls: hills and ridges come to that height on the Murrumbidgee side to give a fairly uniform skyline, while the area in the Rhine Falls-Jindabyne-Adaminaby triangle is slightly higher, with an exceptional point rising to 4,816 feet. The level is again found on the flanks of Yaouk Hill and to the east of Alum Creek, with a fall of varying steepness to the river.

Considering the eastward limit of this high plain, we find an undulating slope to the Monaro peneplain at 3,000 feet within the salient of the Murrumbidgee near Cooma; there is a sharper fall to the west of Peak Creek and about Rhine Falls, through 800 feet in places, but the impressiveness of the feature is lost when the Main Divide is passed, and the south-easterly slope in the drainage area of Wullwye Creek is in a series of irregular undulations over a distance of some miles to the Berridale district. But there are extensions of the Monaro levels behind this eastern face, both along the two main rivers and creeks which have cut back from them, the Murrumbidgee examples being very impressive.

The topography of the basins of Kelly's Plain (3,800 feet), Yaouk (3,600 and 3,700 feet) and Bolairo (3,200 feet) is essentially pre-basaltic, since there is clear evidence of basaltic visitation in the valleys of Bolairo, 600 feet below Monaro ridge, and the other basins also lie below that horizon. A similar inference could be drawn from the relative positions of the Rule's Point basalt (down to 4,250 feet) and the main summit plane between Kelly's Plain and Yaouk, which is about 4,400 feet, and also from the form of Yaouk Plain itself, which is cut across the grain of the country with a perfection not associated with any definitely post-basaltic features anywhere in the region. Yet these basin plains are young when compared with the surface in which they are eroded, since they are

separated by a gorge section through hard quartzites, etc., above Yaouk, while the superior level about 4,400 feet was formed by the bevelling and planation of those hard folded strata, even across the divides—a process that must have occupied a great time, and indicates a corresponding age for the surface concerned.

The position becomes more complex to the east of Adaminaby and Bolairo, for gently shelving plains make their appearance and fall towards the Murrumbidgee along the established creeks: the initial slope from Monaro ridge is steep for 400 or 500 feet down to 3,600 or 3,700 feet above sea-level (up to 30 degrees), whence a gentle grade is assumed through a vertical distance of 200 or 300 feet to a steeper slope towards the river. Ridges and residuals rise close on 4,000 feet (Plate ix), and there is a repetition of the features in the great salient of the river on the opposite bank: the undulating plains of Bolairo are associated with powerful streams and a zone of low resistance, but relics of the higher landscape persist eastward along the right bank of the Murrumbidgee until the converging streams of the Cooma district are reached. The features of the Murrumbidgee are repeated in the Eucumbene drainage, with somewhat different forms owing to a greater proportion of granite on the landscape: this is especially the case in the Berridale-Dalgety section, but along the eastern side of the Eucumbene between Adaminaby and Jindabyne the high level plains at 3,800 to 3,900 feet break sharply to the uniform valley wall, with a fall of the order of 500 feet to the river, rounded forms being characteristic of higher points and of minor features. There are limited plains along the course of the main stream, the principal being in front of Alpine Hill (3,700 feet), Adaminaby (3,500 feet) and at Jindabyne (2,800 feet), the second being the most notable because it extends up the broad valley of Fryingpan Creek, a stream flowing against the general run of others.

From these facts, it seems that the plain which rises from 4,100 feet at Rhine Falls to 4,400 feet west of Adaminaby is the main feature of this part of Monaro; that it was cut in a higher mass that still occurs in a much reduced form to the north and west, including the highest land on either side of the northerly Murrumbidgee. Further erosion of the features above 4,000 feet has caused a general lowering towards the east, and a selective cutting of local plains along the courses of the main streams down to the level of the Monaro peneplain, which may be coeval with them, despite its great extent and level character over eastern Monaro. The surface variety which Browne describes along the northerly Murrumbidgee lends support to this contention, because it shows how sudden a change is possible from low to high relief with the geological variation found in the region. It would appear that the only place where block-faulting has been indicated as a comparatively recent possibility is in the Kosciusko plateau which rises above 6,000 feet, and the probable fault indicated by David (1908) as throwing 200 feet at Pretty Point is some indication of the magnitude of individual displacements to be expected towards the limits of that restricted area. It is not suggested that warping and faulting did not occur elsewhere on the tablelands which have been described, but that such movements were of a minor character and had comparatively little influence on the surface features, which are essentially due to the erosion of a mass that has been subjected to fairly uniform vertical movements since closing Palaeozoic time. This idea accords with the stream relationships.

Streams of Monaro.—The first account of the streams of the region is found in the narrative of W. B. Clarke, who correlated the streams having meridional

tendencies with the grain of the country, folding, and the occurrence of soft zones, while the others were recognized as following definite fractures which fall into a series of families, the principal trending NW–SE, NE–SW, and E–W: rivers of the Bombala district were ascribed to a surface depression and contrasted with those radiating from Kosciusko, a point of maximum uplift. David (1908) added late Tertiary block-faulting about Kosciusko as a causative factor in the development of the present shape of the Crackenback and Snowy, while Sussmilch (1909) developed a similar idea with respect to the northerly Murrumbidgee, which he conceived to have come into existence as the result of warping and faulting of a peneplain surface raised unevenly to form the present highlands. He believed that the upper Murrumbidgee and the southern part of its meridional course originally discharged to the Snowy, thus following Clarke in principle, who had described Monaro ridge as an anticlinal feature, and had referred to great stream dislocations as the result of basalt flows. Griffith Taylor's opinions with respect to the Murrumbidgee were rather similar, but he argued more from the evidence of stream shapes, and held that the tributaries flowing contrary to the general northerly direction of the Murrumbidgee belonged to an earlier southward flowing system. Doubt was cast on some aspects of these views by Browne (1928), who described the valley of the northerly Murrumbidgee as a non-tectonic feature, and by Craft's (1932*a*) demonstration of the parallel Shoalhaven area as one that had suffered no appreciable differential uplift from north to south over a period antedating the basalt flows and coming to the present time, and whose features extend normally into the Murrumbidgee basin.

The correlation of the stream lines with a definite fracture pattern is sound, and requires no further elaboration, but they may also be classified by reference to the stage of development of their various networks, and may be grouped under three headings, namely: (i) Those which have failed to develop a complex system of tributaries: the Cotter, Gudgenby, Naas, much of the upper Snowy and of the northerly Murrumbidgee are included. (ii) Those which present a minutely branching system, such as Queanbeyan and Bredbo Rivers and Alum Creek. (iii) Those which have integrated their tributaries into a few large, evenly spaced branches: this class is of particular importance, since it comprises the Murrumbidgee and Eucumbene-Snowy systems on either side of Monaro ridge.

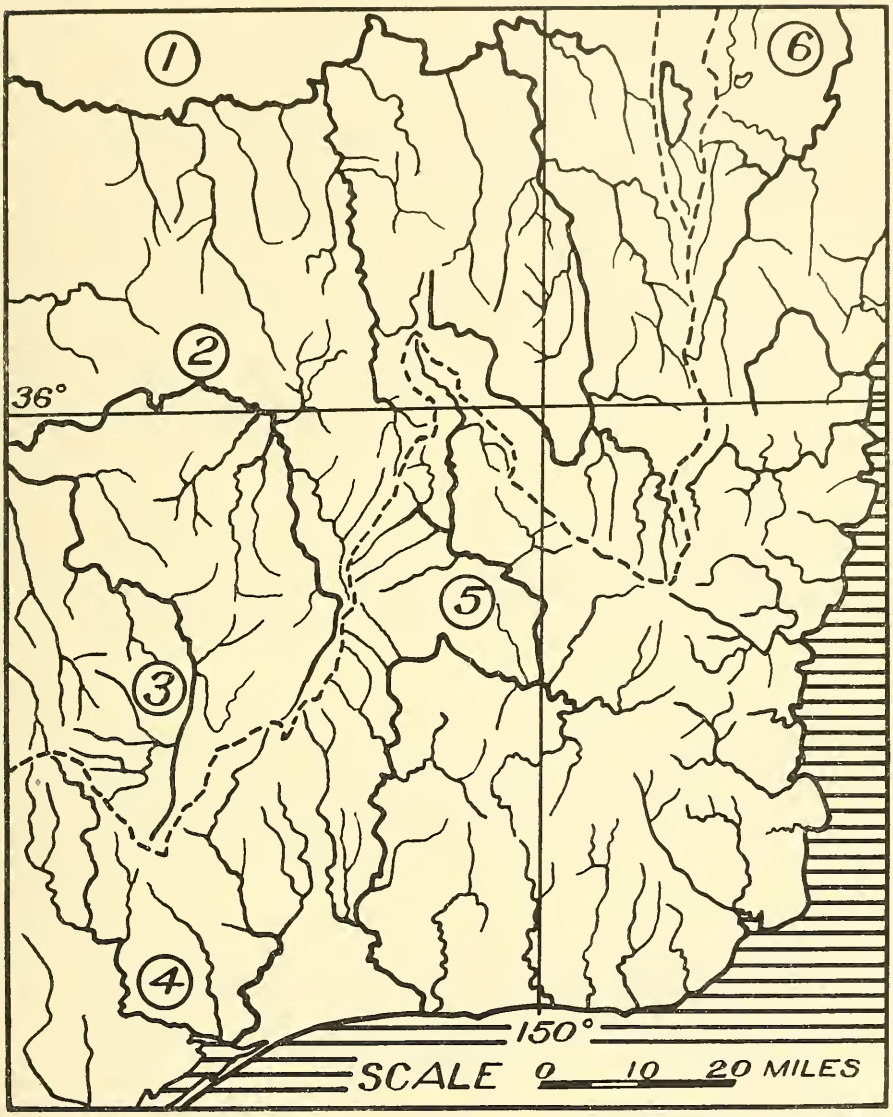
Of these three, the first class has been most powerfully influenced by geological structure: the Cotter, Naas and northerly Murrumbidgee flow along zones of weakness flanked by persistently hard ridges, while the Gudgenby and upper Snowy are marked by linear courses, clean angular junctions, and restriction to well defined fissures, suggesting development along these to the general detriment of the pattern, and a lack of closely spaced minor weaknesses to give rise to smaller streams. In the second class, each small tributary flows in a distinctive valley of its own, and there is a correlation with high ridgy or terraced country which the multitude of streams is unable to reduce efficiently.

The third class is of a composite nature, and its various members have developed under a variety of circumstances. West of Yaouk and Adaminaby the simplification of patterns appears to have been effected by heavy rainfall on a weathering landscape, and the identity of some of the existing streams is almost lost where they flow across level swamps. East of Adaminaby, the minor valleys have been greatly widened and are frequently of a trough shape, with a degeneration to broad, shallow hollows with only a few definite watercourses to collect the

run-off from the gentle surfaces: this is the case in both granite and basalt areas, whose streams are remarkably similar to one another in plan, despite the fact that hundreds of feet of basalt have been removed from parts of the Monaro peneplain while other rocks have suffered comparatively little denudation. In the Umaralla drainage, the present stream system appears to have been inherited in detail from the Monaro peneplain at 3,300 feet, although not much of it now flows over that surface: dissection has not caused a complex system of tributaries to develop on the hillsides and ridges as in the country immediately to the north, possibly on account of insufficient rainfall (the rainfall at Cooma, under rather similar conditions, averages 19 inches per annum). Thus the great feature of Monaro is the presence of a genetic stream type both on the more ancient surfaces, and in places affected by basalt flows; the spacing and general arrangement of tributaries shows considerable uniformity, and it is not a fortuitous circumstance that the distribution of the three types should be ordered as it is: the first two are associated with lands that persist at a relatively high elevation, while the third is virtually confined to those parts which have been susceptible to peneplanation in the more distant past, and to elimination of surplus tributaries in more recent times.

Stream Origins. (Text-figs. 3 and 4.)

The Monaro region is notable as the place where the Main Divide of New South Wales makes a westward turn into Victoria. Perhaps it is this circumstance allied with the general flatness of the continent which has led to the highlands about Kosciusko being described as an Alpine knot, but the term is hardly applicable, as the plateau is a relatively simple surface crossed by low erosional ridges, which are not obscured by possible block faulting about Kosciusko itself and in the neighbouring highlands of Victoria, although deep gorges give a complex topography in places. There is no reason why the co-extensive plateaus and drainage systems in the two States should be considered apart from one another, and they have one salient drainage feature in common in the presence of meridional streams discharging northward to the Murray or Murrumbidgee, or southward to Bass Strait (Text-fig. 3). Apart from the fringe of Pacific coastal streams, the Main Divide is a simple affair with opposed salients at the heads of the Snowy and Mitta Rivers, and a dominant east-west trend. It has been indicated that the Shoalhaven-Murrumbidgee family may be descendants of ancient longitudinal streams flowing northward to the Permo-Triassic depression, a suggestion which is in line with the evidence cited by David (1911), and others whom he quotes, to indicate that the Victorian Main Divide was essentially developed at the close of the Palaeozoic or the beginning of the Mesozoic era. The streams of the region thus originated parallel to the ancient grain of the country, and have had their expansion confined by zones of hard rock or of specially resistant features: it is only in Monaro, to the south of the geologically varied Federal Territory-Gourock mass that a wide area of more uniform rocks has allowed the ready development of peneplain features, and the formation of more extensive stream systems. The straight eastern divide shows the uniformity of attack from the Pacific or, perhaps, the uniform resistance offered by meridional trends, and the modern piercing of the divide to the east of the Shoalhaven is readily explained in terms of nearness to the coast and the strong attack by revived streams along definite lines of weakness.

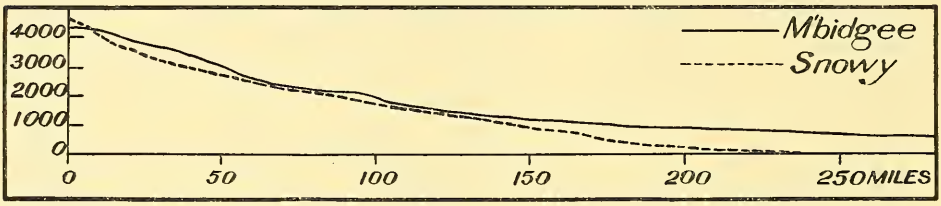


Text-fig. 3.—General Stream Pattern of the extreme south-east of Australia. The Main Divide is shown by a broken line, and the principal streams are: 1, Murrumbidgee; 2, Murray; 3, Mitta; 4, Mitchell; 5, Snowy; 6, Shoalhaven.

As Clarke suggested, it is possible that the eastern Snowy drainage was originally directed towards a depression discharging westward to the lower Snowy, but the present lowering of surfaces is to be attributed to erosion because the high points lie in a definite summit plane. In plan, the pattern suggests development from a main east-west tributary of the Snowy through Bombala, with an overgrown branch extending towards the north-west. It might be sug-

gested, as an interesting speculation, that the upper Murrumbidgee, which is placed roughly between the Federal Territory granites and those of Dalgety-Kosciusko, can only be explained in some such manner, and although it cuts across granite lines in places and is well adjusted to structure, it may have originated in an old high-level depression that persisted from the time of the last folding movements and granite intrusions to which the region was subjected: the possibility of such an explanation being feasible is shown by the stability of the streams as far back as definite physiographic records go.

Sussmilch (1909) and Taylor (1910) have suggested that the upper Murrumbidgee originally flowed to the Snowy, whence it was diverted northward by capture following warping and basalt flows. The balance of both pre- and post-basaltic erosional features on either side of the present Main Divide does not favour the idea, and there is no certain evidence of considerable warping. Moreover, the Umaralla appears to have discharged northward over a very long period

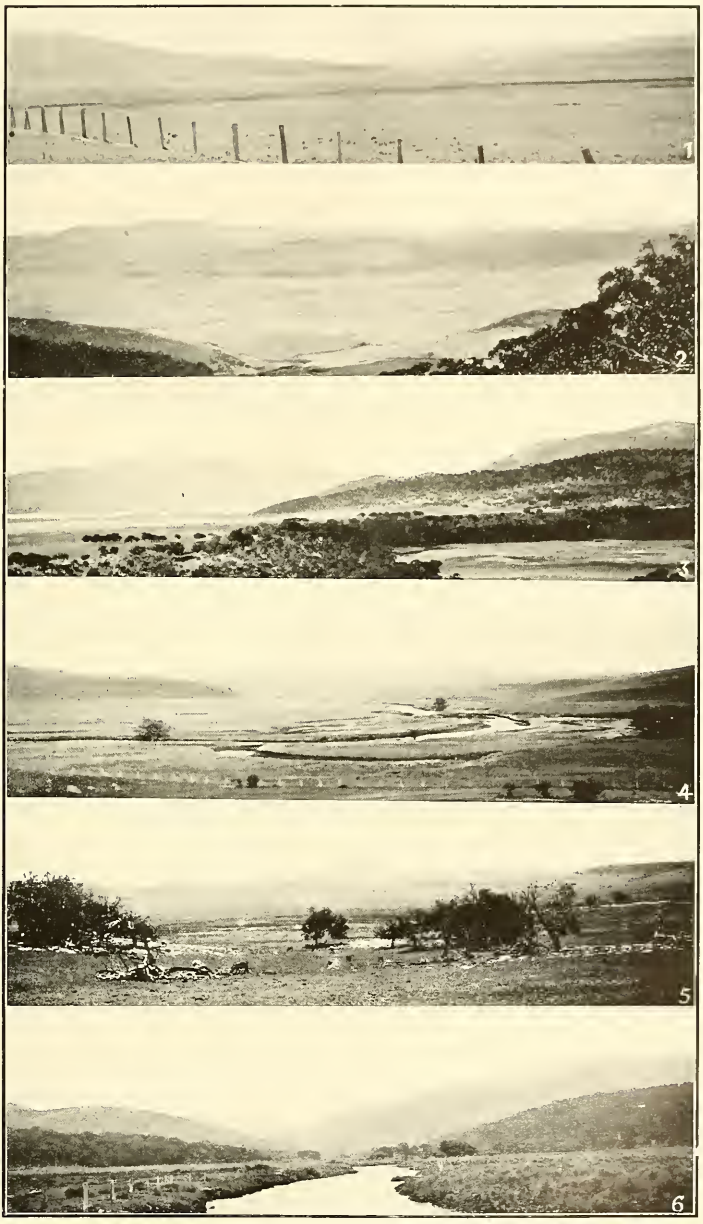


Text-fig. 4.—Profiles (Talwege) of the Murrumbidgee and Eucumbene-Snowy Rivers. Vertical exaggeration = 50.

of time, and there are no features rising above the level of the Monaro peneplain between it and the Murrumbidgee, and no suggestion of an old divide. Considering the profiles of the main streams (Text-fig. 4), it will be seen that they are very similar over the upper parts of the courses, in which the streams flow on opposite sides of Monaro ridge, although the revived lower part of the Snowy has a steeper fall to the nearer coast. Simultaneous development to a comparable stage is shown for the two rivers, and the probability of a major capture in their history of the nature suggested is exceedingly remote. It is true that the Eucumbene has established new courses about Kiandra, but this seems to give a measure of the change of the two systems with respect to one another. The existing divide has been an essentially stable feature over a long period of time, antedating the basalt flows considerably.

Summary.

The Monaro region appears to have been elevated above the country to the east, probably in closing Palaeozoic or early Mesozoic times, after the reduction of the dominant Kanimbla (Hercynian) features. Since then, it appears to have been subjected to a series of epeirogenic uplifts which induced widespread peneplanation, of decreasing completeness to the west and north. Relics of the original surface at 5,000 feet or more compare with the level-bedded Devonian rocks towards the eastern divide about 4,000 feet, and peneplain levels exist at 4,000 to 4,400 feet and about 3,200 feet respectively, the latter (Monaro peneplain) being comparable with the older features of the Shoalhaven Valley. The development of steeper-sided valleys towards the east was proceeding before the outpourings of the ("newer" or upper Tertiary) basalts, and more recent



Monaro District, N.S.W.